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XRT data analysis software developed by

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L. Angelini, HEASARC

ASDC=> ASI Science Data Center

ASDC+OAB => ISAC (Italian Swift Archive Center)

Overview

Mode description :

- General description
- Software on board & correction needed

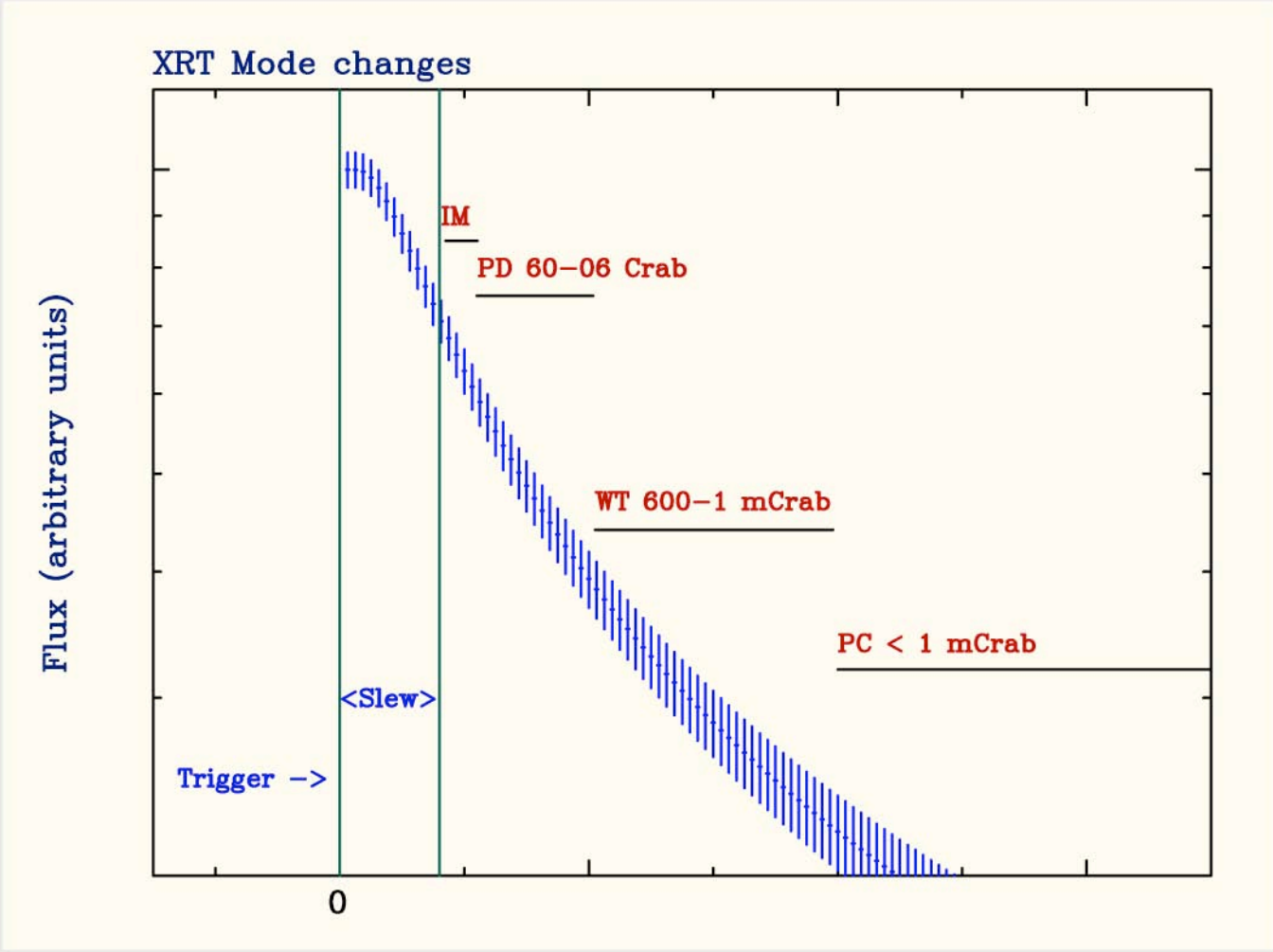
What the ground software does to the data

Description of the processing

- Overall pipeline x mode
  - Tasks
  - Screening
  - Example outputs
- All in one command

TDRSS messages : first look of the GRB

XRT : first view at the GRB



- First time on GRB mode changes automatically based on source flux.
- Immediate response calculated on board consist of messages send via TDRSS:
  - Position & Image
  - Spectra PD and WT
  - Lightcurve 100 bins

Imaging mode

Collect data per pixel

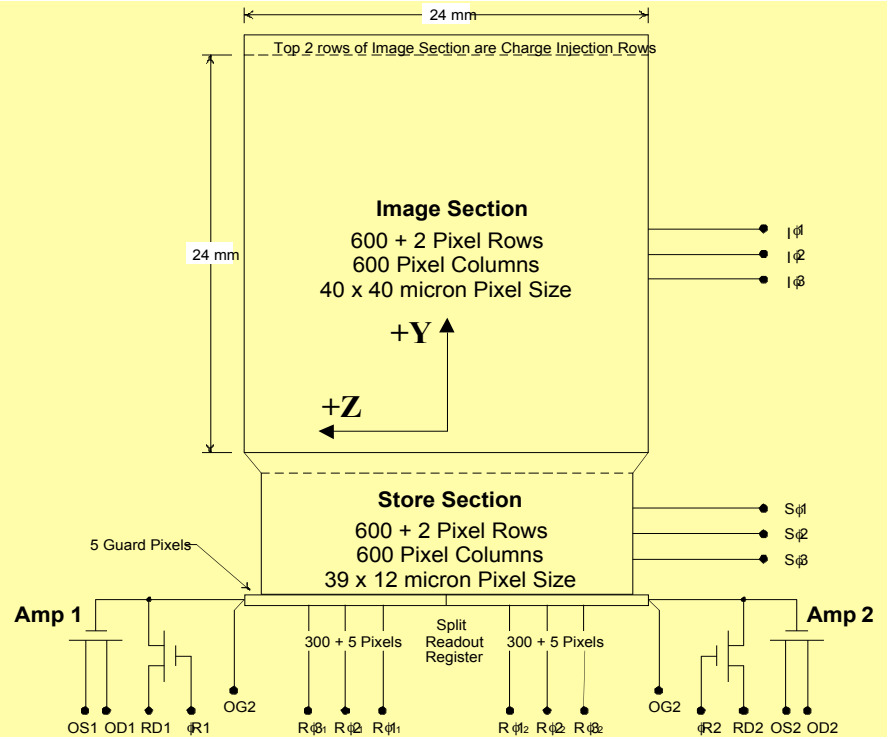
- Each pixel contains the total DN value collected in that pixel
- Only pixel above the Lower Level Discriminator (~40 DN) are sent
- No bias subtracted or event recognition

= > Main use : determine position & flux as soon as on source

Flux limits : 45 Crab -25 mCrab

Telemetry information

- Pixel Raw X & Raw Y and DN
- Raw X 0-599 Raw Y 0-601
  - ..but TDRSS only 51x51 is sent on ground
- RAWY 600-601 are not used
  - Raw Y 600-601 Charge Injection Pixel
- Two integration time 0.1 & 2.5 s
  - Short and long imaging
- Data can be read by Amp1 or Amp2
  - Different numbering of the pixels
  - By default Amp2



Photodiode mode

Collect data all CCD (no spatial information)

- 1 Serial and 1 parallel transfers are alternate :
  - All diagonal CCD pixels contribute to a change of a read out pixel
  - Pixels with calibration sources contribute as well

  = > Expect image dominated by the GRB
- On board software allows to send data with & without bias subtraction (default subtracted)
- LL & UL discriminator (two submode)
  - Low rate :within 150 & 4000 discriminator (LR)
  - Piled up : all pixels (no discriminator applied) (PD)
- No on board event recognition

= > Main use : High resolution Spect. (140 eV @ 5.9 keV), fast Timing as soon as on source

Flux Limits : 60 Crab - 0.6 Crab

Telemetry information

- DN value cumulative within a ΔT and pixel location in the telemetry frame (Offset)
  - ΔT sum of serial & parallel transfers (but for about the first 1850 pixels)
- Integration time frame ~8 seconds
  - Event tag on ground (0.14 ms time resolution)
- Data can be read by Amp1 or Amp2
  - Different numbering of the pixels

    Relevant for location source position & how pixel are counted in the event recognition
  - By default is Amp1

Windowed Timing mode

Collect data per row (one dimension collapsed)

- Every readout contains the sum of 10 CCD rows
- One telemetry frame contains 600 of these read outs
- Bias row subtracted on board for each readout
- No on board event recognition
- Data telemetered with 40-4000 (LLD & ULD respectively)

= > Main use : High resolution Spectroscopy, fast Timing , one-dimension image

Flux Limits : 0.6 Crab - 1 mCrab

Telemetry information

- Pixel RAWX, its DN value and the Y dimension in the telemetry frame (Offset)
- 200 RAWX pixels telemetered (100 pixels each side from reference position at 300)
  - Cal sources are excluded
- Integration time per frame 1.06 seconds (per 200 RAWX pixels)
  - Event tag on ground (2.2. msec time resolution) :

    all pixels within the same read-out have the same ΔT
- Data can be read by Amp1 or Amp2
  - Different numbering of the pixels
  - By default Amp1

Photon Counting mode

Collect data per pixel

- Each pixel contains the total charge collected on that pixel
- Bias map subtracted per frame on-board
- On board event recognition uses 5x5 matrix (external are guard pixels)
- Telemetered only recognized event with a 3x3 matrix
  - but not grade is assigned on board

= > Main use : High resolution Spectroscopy, Two dimension image, moderate Timing

Flux Limits : < 1 mCrab

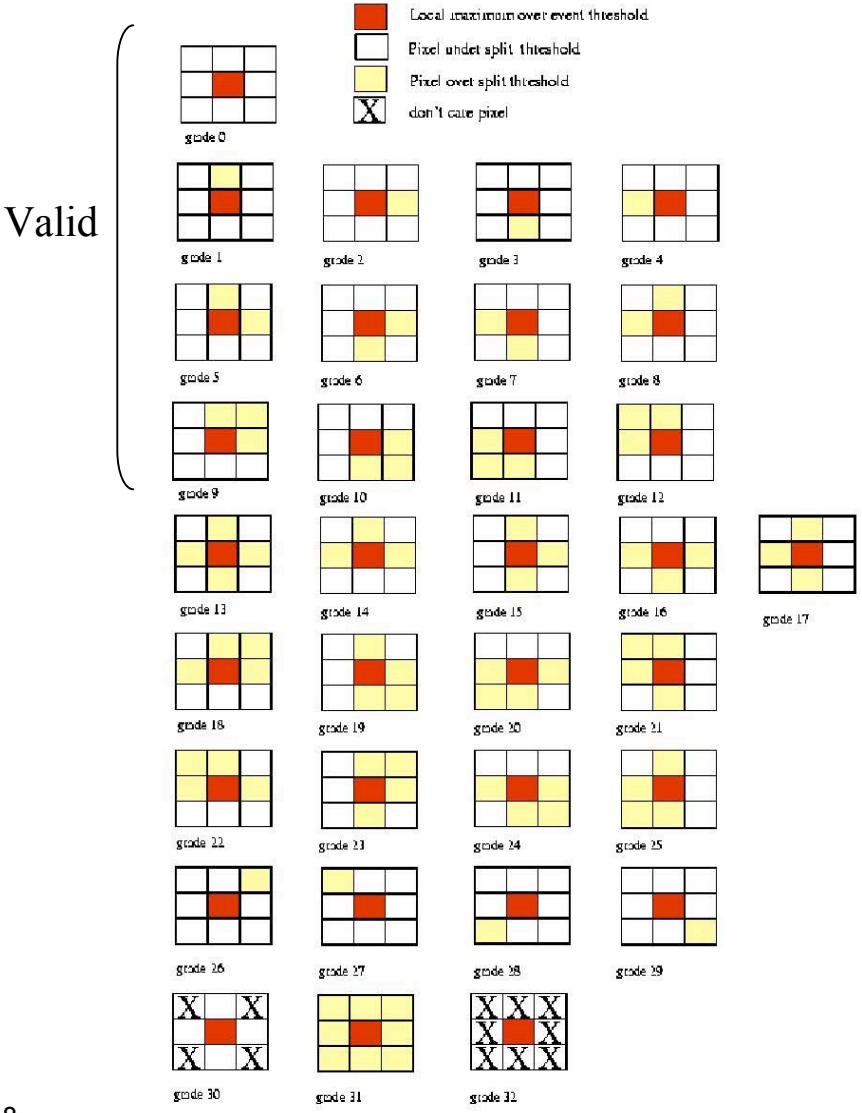
Telemetry information

- Event Raw X & Raw Y and the DN 3x3 matrix
  - Event coordinates from the central pixel of the 3x3 matrix
- Raw X 0-599 Raw Y 0-599
  - Depending on the window setting cal sources are included
- Integration time 2.5 sec (resolution of the vents)
- Data can be read by Amp1 or Amp2
  - Different numbering of the pixels
  - By default Amp1

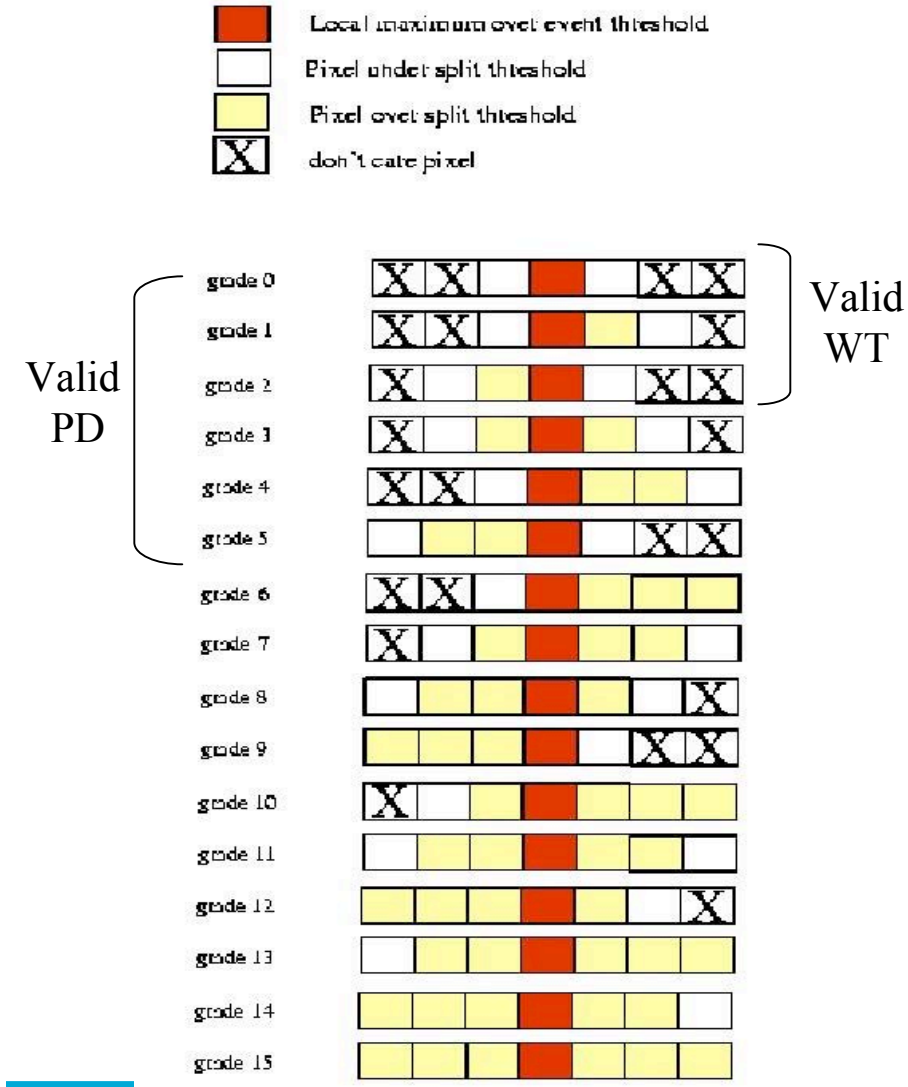
6	7	8
4	0	5
1	2	3

Grade distribution

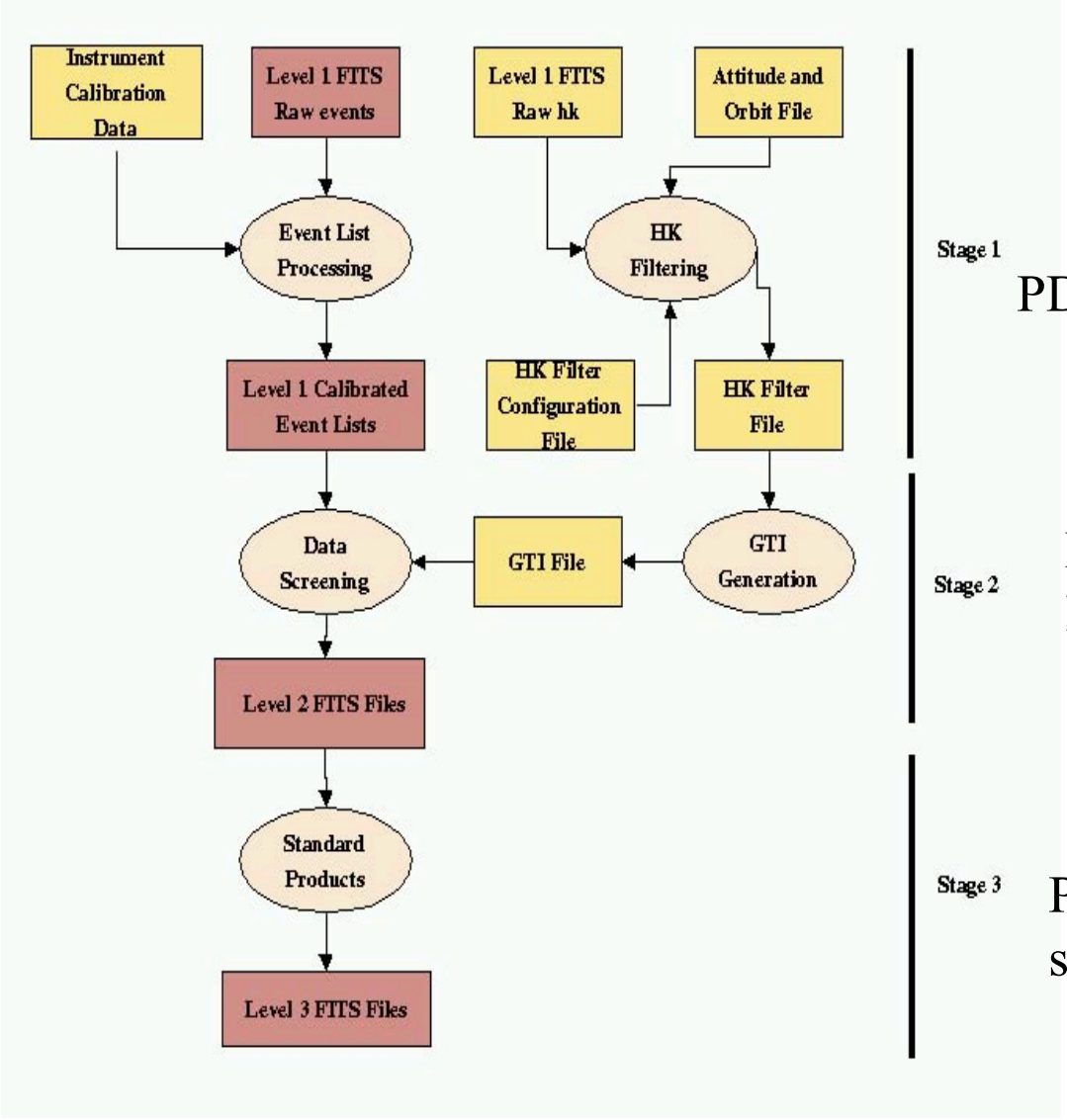
PC mode



WT & PD



Overall software description



IM: RAW coordinates
PD & WT & PC: Unfiltered events

IM: SKY coordinates
PD & WT& PC: CLEAN events

PD & WT & PC: average spectrum, arf & lightcurve

Data in FITS

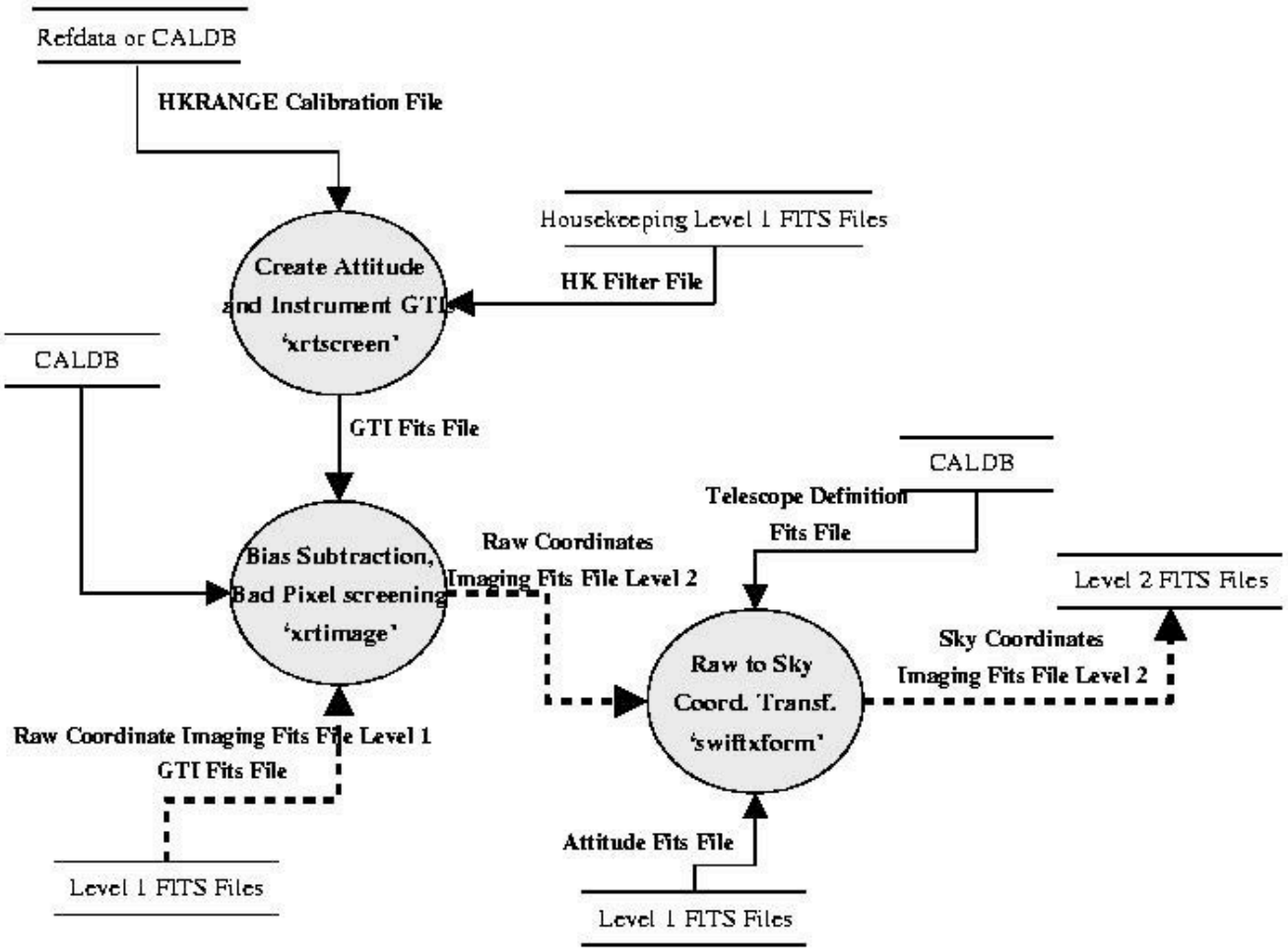
Imaging mode :

- File FITS type : Image extension
  Array NxM each pixel containing the DN value
- XRT File : multiple extensions (each containing a frame)
  - One observation is expected to contain two Image extensions (e.g. short and long when arrive the first time on that GRB)
  - Same format maintained through the processing

Photodiode, Windowed Timing & Photon Counting :

- File FITS type : Bintable Event + GTI extensions
  Event : Pixel/event characteristics stored in separate columns
  GTI: Start and stop time in columns
- XRT File : One event and one GTI extensions (All frames)
  - One observation contains : is expected to have only one PC file
    One WT file
    One LR and PD file in stable pointing
    One LR file for slew and one when pointing is within 10 arcmin
    One PC file. Multiple only if the window setting is changed
  - Same format is maintained through the processing
    - Not all columns are maintained between Level 1 & 2

Imaging


Refdata or CALDB
HKRANGE Calibration File
Housekeeping Level 1 FITS Files
HK Filter File
Create Attitude and Instrument GTI 'xrtscreen'
CALDB
GTI Fits File
CALDB
Telescope Definition Fits File
Bias Subtraction, Bad Pixel screening 'xrtimage'
Raw Coordinates Imaging Fits File Level 2
Level 2 FITS Files
Raw to Sky Coord. Transf. 'swiftxform'
Sky Coordinates Imaging Fits File Level 2
Raw Coordinate Imaging Fits File Level 1 GTI Fits File
Level 1 FITS Files
Attitude Fits File
Level 1 FITS Files

Imaging processing

xrtscreen:

- create a GTI file based on the attitude and HK parameters
- Info from : CALDB HK range & HK filter file

  Output: GTI file

xrtimage:

- Subtracts bias. Blank pixels if : bad, saturated or calibration source.
- Info from: bad pixels list & bias (CALDB)

  Output: Temporary Image file

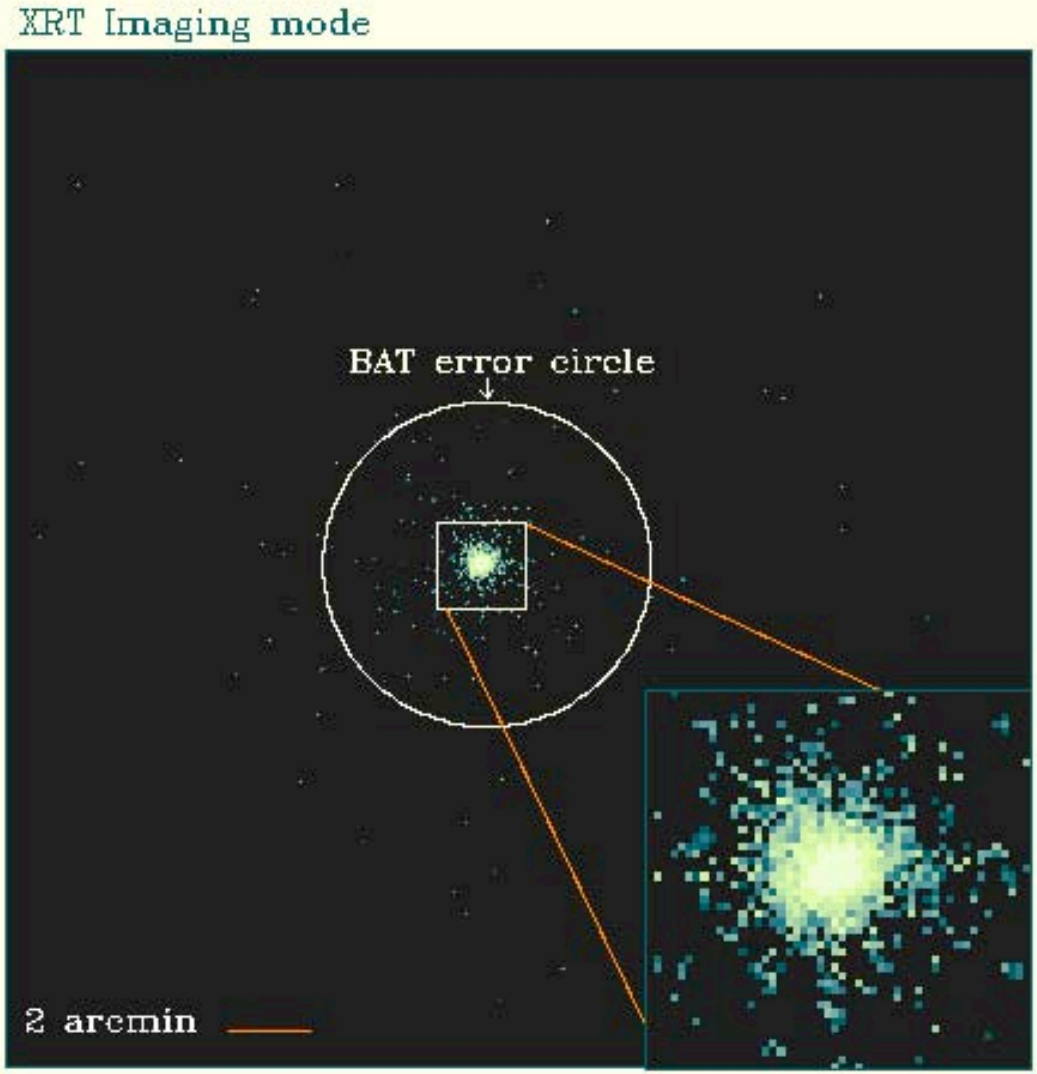
swiftxform:

- Transforms coordinates from RAW to DET or SKY.
- Info from: satellite attitude & the CALDB "teldef"

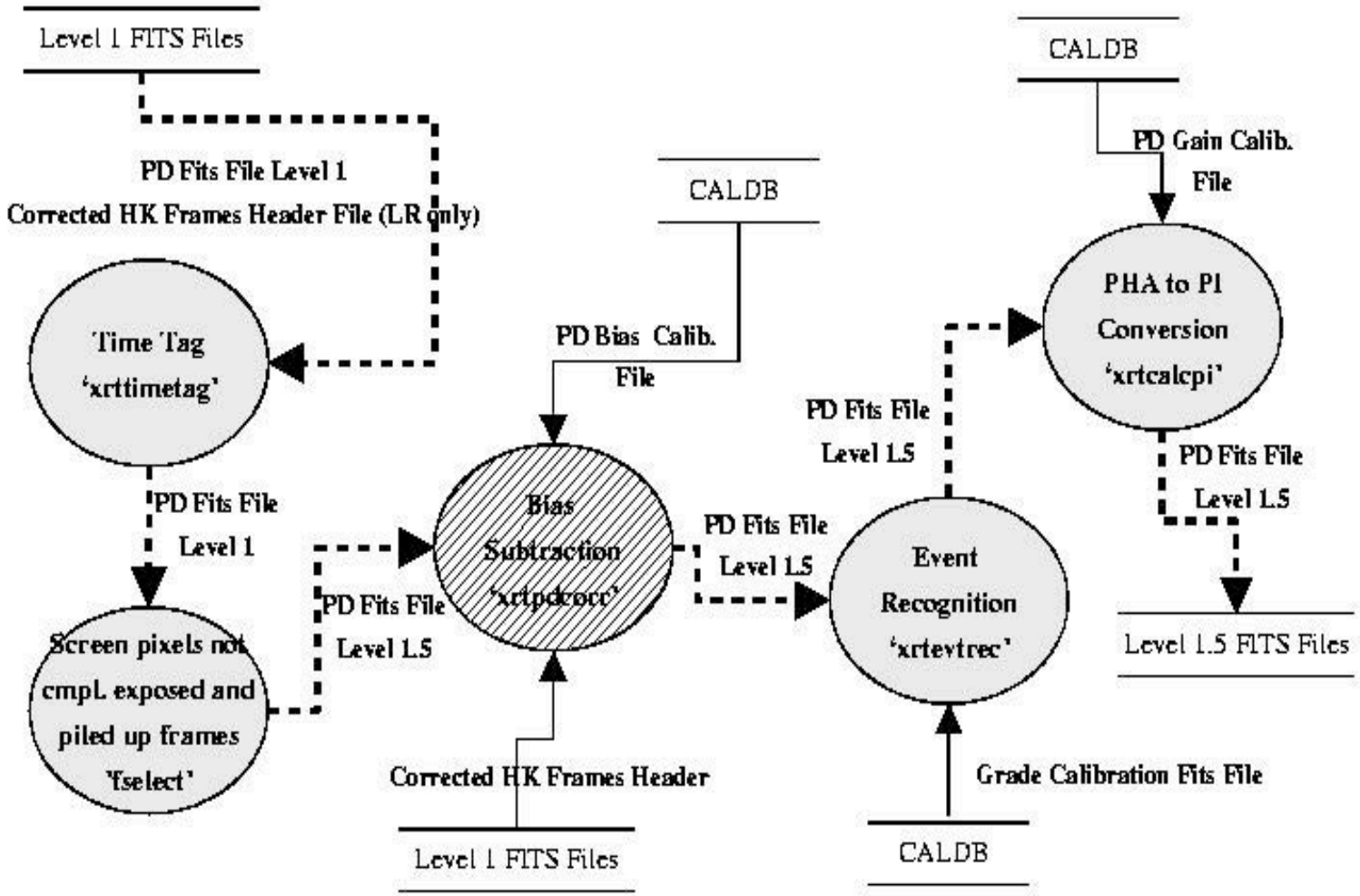
  Output: Image file Level 2 with transformed coordinates

⇒Screening for the GTI is not applied since there is only one frame (an exposure)
However the good GTI are appended in the output files

Imaging picture



Photodiode


Level 1 FITS Files
PD Fits File Level 1
Corrected HK Frames Header File (LR only)
CALDB
PD Bias Calib. File
CALDB
PD Gain Calib. File
PHA to PI Conversion 'xrtcalcpi'
Time Tag 'xrttimetag'
PD Fits File Level 1
PD Fits File Level 1.5
PD Fits File Level 1.5
Bias Subtraction 'xrtpdcorr'
PD Fits File Level 1.5
Event Recognition 'xrtevtrec'
Level 1.5 FITS Files
Screen pixels not cmpl. exposed and piled up frames 'fselect'
Corrected HK Frames Header
Level 1 FITS Files
Grade Calibration Fits File
CALDB

Photodiode processing - Level 1

xrttimetag:

- Calcultes photon arrival time using a source position.
  - Source DETX/Y stored in the columns of the output file.
  - GTI extension updated with frame time.
- Info from : satellite attitude & the CALDB "teldef "

Output: event file with tagged times in column TIME and GTI extension

fselect:

- eliminates pixels not fully exposed and frames affected by pile-up

xrtpdcorr:

- Subtract the bias. Bias value can be:
  - a constant value (from CALDB file or input by user)
  - a value calculated via statistical methods using pixels below threshold (PU) or last 20 pixels of each frame telemetered (LR)

Output :event file with PHA corrected

By default this correction is done on board

Photodiode & Windowed - Level 1a

xrtevtrec:

- Event recognition using 7x1 pixels array, assigns PHA and GRADE
  - PHA: summing PHA of the pixels above split threshold
  - GRADE: values assigned following the scheme stored in a CALDB file
- Info from: grade definition (CALDB)

  Output: event file with events reconstructed

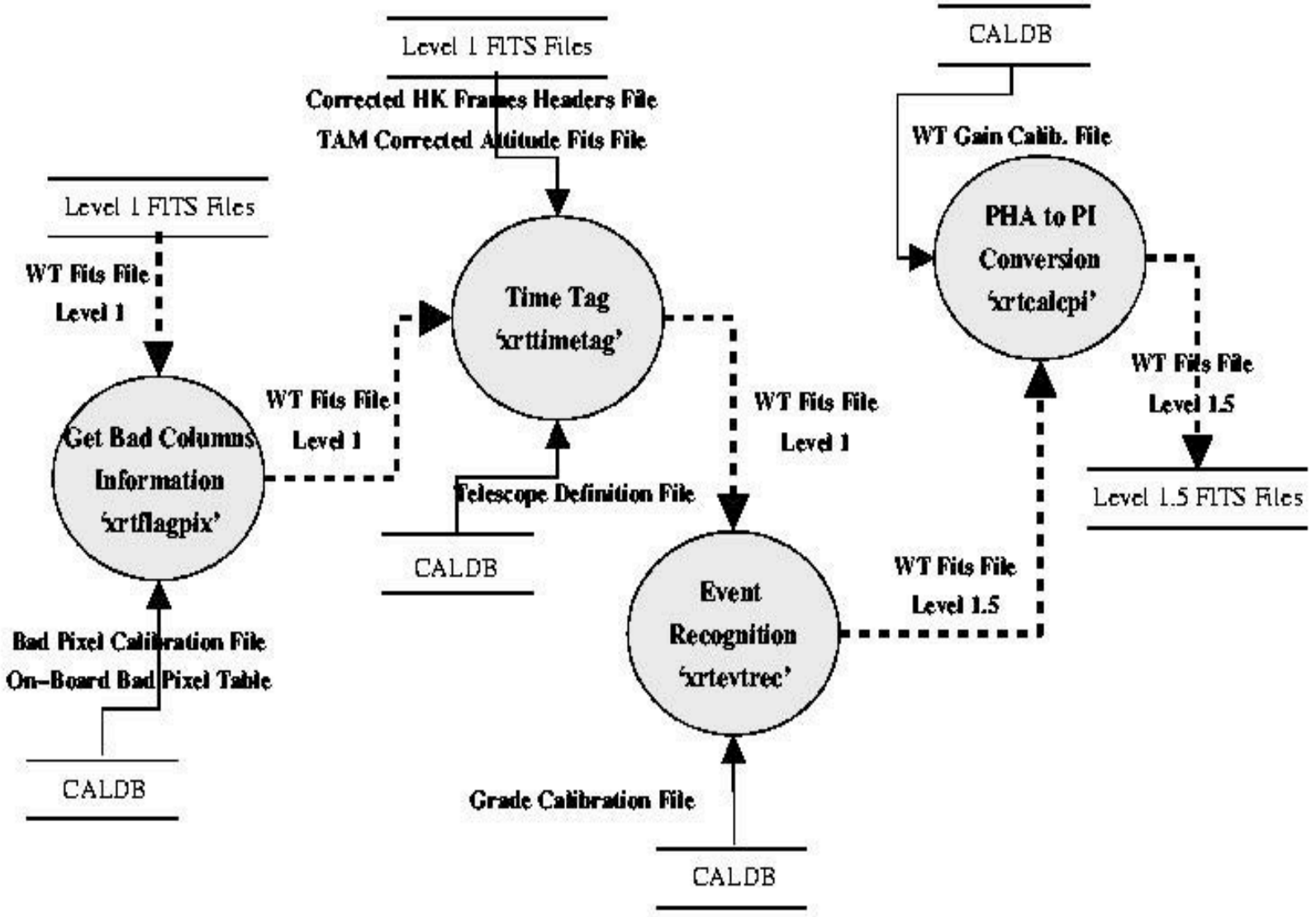
xrtcalcpi:

- Assigns PI values accounting for :
  - temporal changes in gain, induced by radiation damage
  - differences in gain with the position, due to the CTI
- Info from : gain file (CALDB)

  Output: event file with PI column calculated

=> END on Stage 1

Window Timing



Windowed Timing processing - Level 1

xrtflagpix:

- Flags events if bad columns. Flags values set in the column STATUS.
- Info from : bad pixels (CALDB standard on board & CAL Team list)

  Output: event file with STATUS column filled

xrttimetag:

- Computes photon arrival time (assuming all events from the source).
  - DETX (computed) and source DETY stored in output file columns
  - GTI extension updated with frame time
- Info from : satellite attitude & the CALDB "teldef "

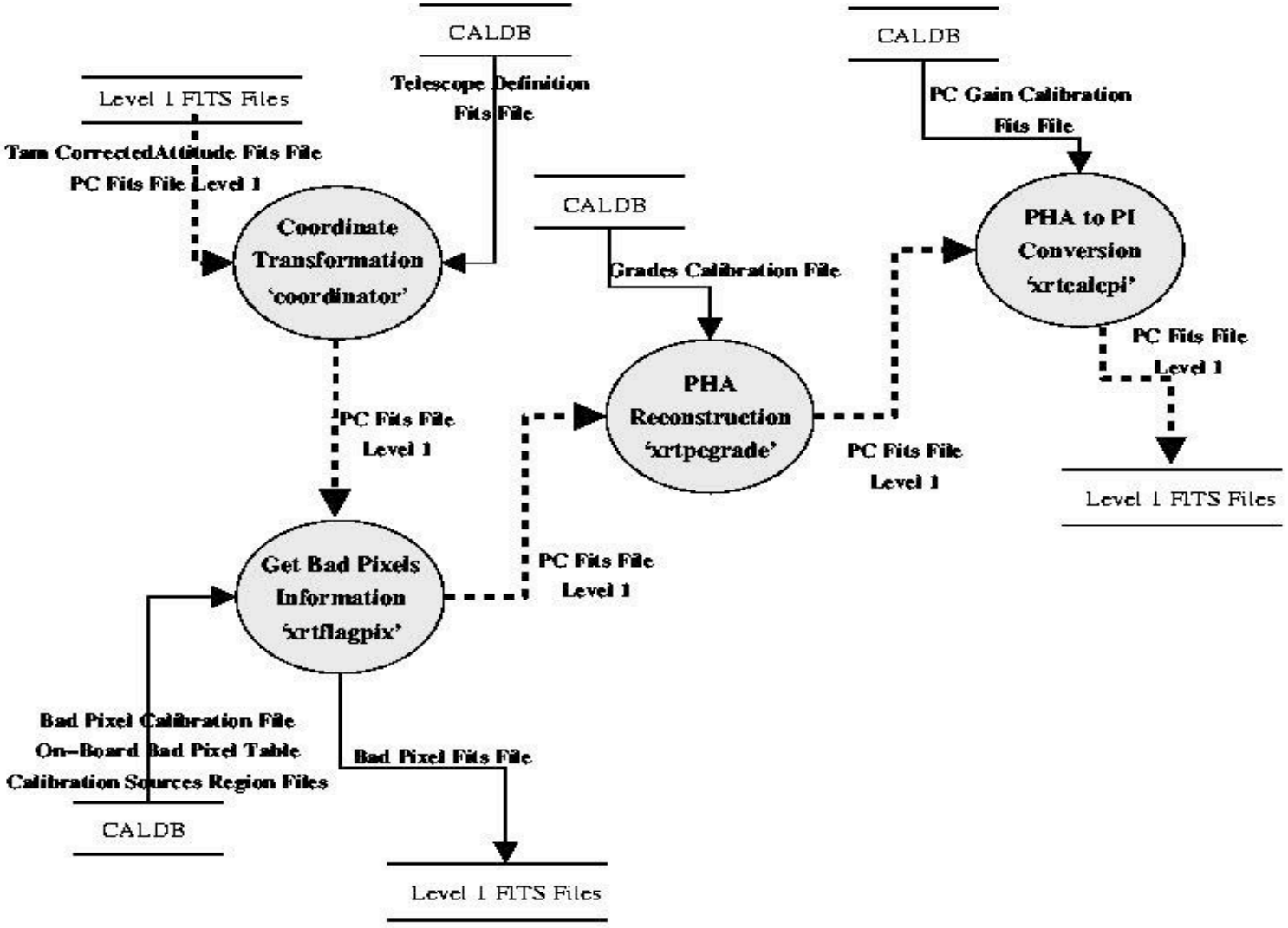
  Output: event file with tagged times in column TIME and GTI extension

⇒After the processing is identical to the Photodiode mode data:

xrtevtrec & xrtcalcpi

⇒End of Stage 1

Photon Counting



Photon Counting processing - I

coordinator:

- Transforms coordinates from RAW to DET and SKY
- Info from : satellite attitude & CALDB "teldef" file

  Output: event file with detector & sky coordinates

xrtflagpix:

- Flags events if in bad pixels or columns or at calibration sources position. Flags set in the column STATUS.
- Info from : bad pixels (CALDB standard on board & CAL Team list)

  Output: event file with STATUS column filled

xrtpcgrade:

- Computes a single PHA value and assigns event grade.
  - PHA: summing PHA of the pixels above split threshold in the 3x3 matrix.
  - GRADE: values assigned following the scheme stored in a CALDB file (XMM like)
- Info from: grade definition (CALDB)

  Output: event file with PHA and GRADE

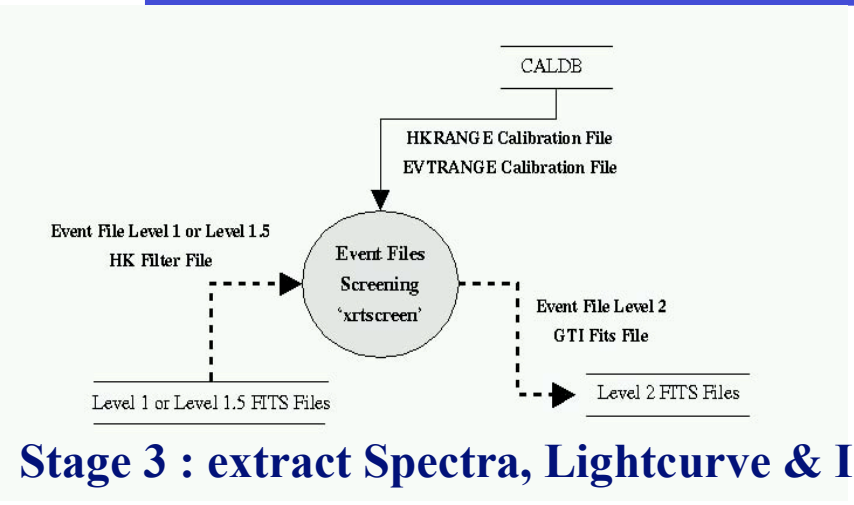
xrtcalcpi:

- Assigns PI values accounting for :
  - Gain temporal changes, induced by radiation damage; Gain position dependence, due to the CTI
- Info from : gain file (CALDB)

  Output: event file with PI column calculated

=> END of Stage 1

Screening & products : common to all event modes



xrtscreen: Generates GTI and/or screen events

– GTI via a boolean expression operating on filter file parameters

–Screens events selecting standard range values in the STATUS & GRADE columns (screening based on other columns is also possible)

Output : Level 2

=> End of Stage 2

Stage 3 : extract Spectra, Lightcurve & Images

xselect :

–Extract products for different selection (e.g. time,intensity phase or region)

–Used also with ROSAT ASCA BeppoSAX Chandra & XMM-Newton

–Standard usage for PD &WT &PC mode :

–PD bin all data to extract a spectrum and lightcurve

– WT & PC select standard region & after bin all data to extract spectrum lightcurve & image

xrtmkarf :

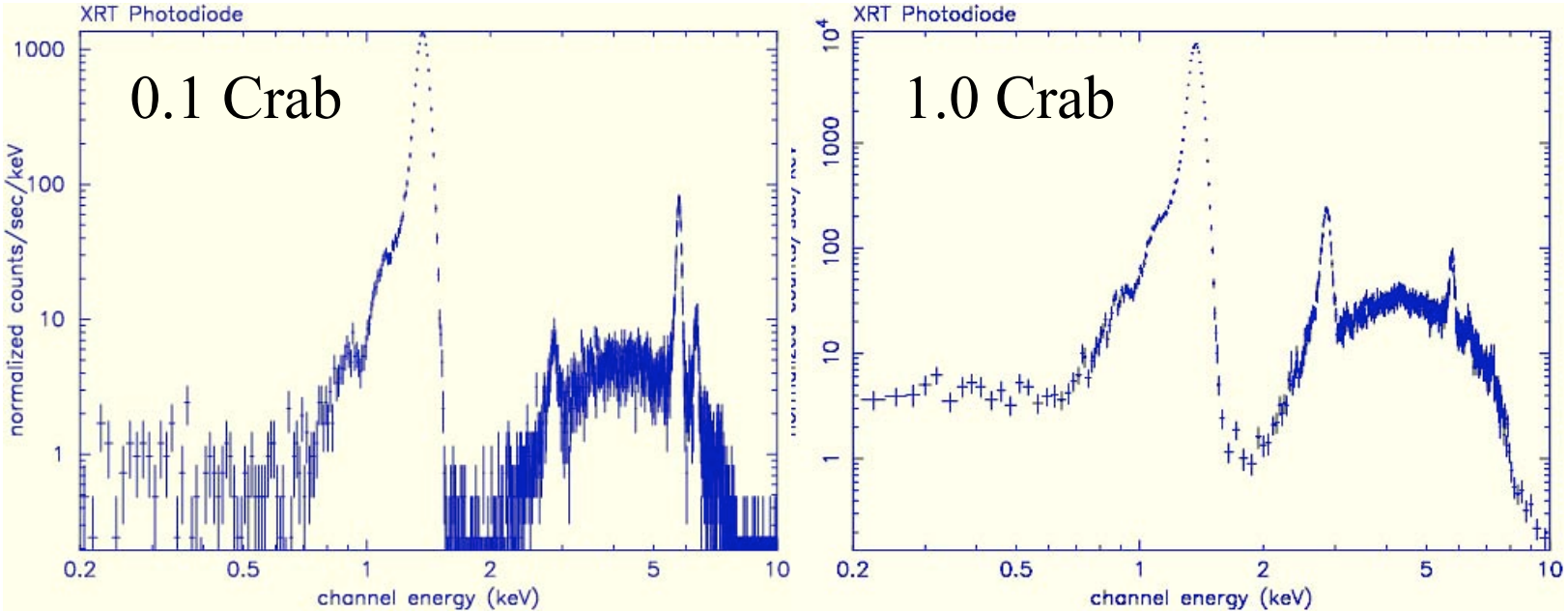
-Calculate an arf for the PD WT and PC mode for a given input spectrum and response matrix.

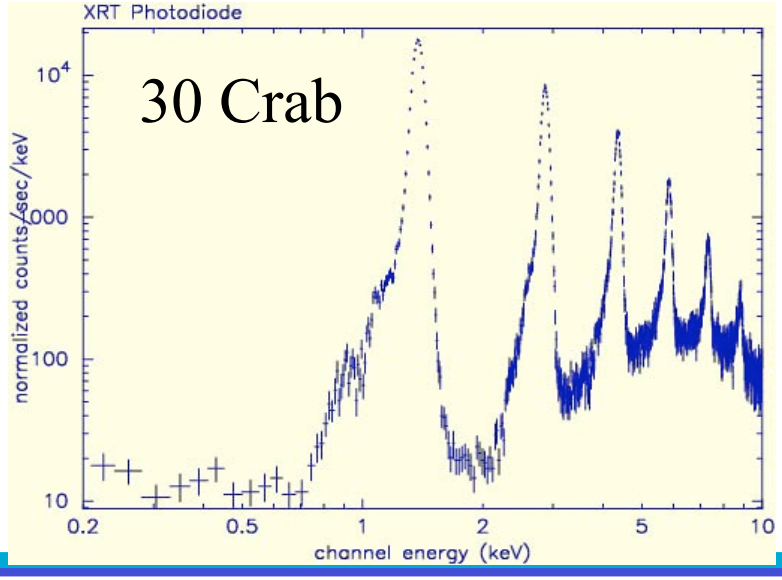
XRT response files for all modes are stored in CALDB.

xrproducts :

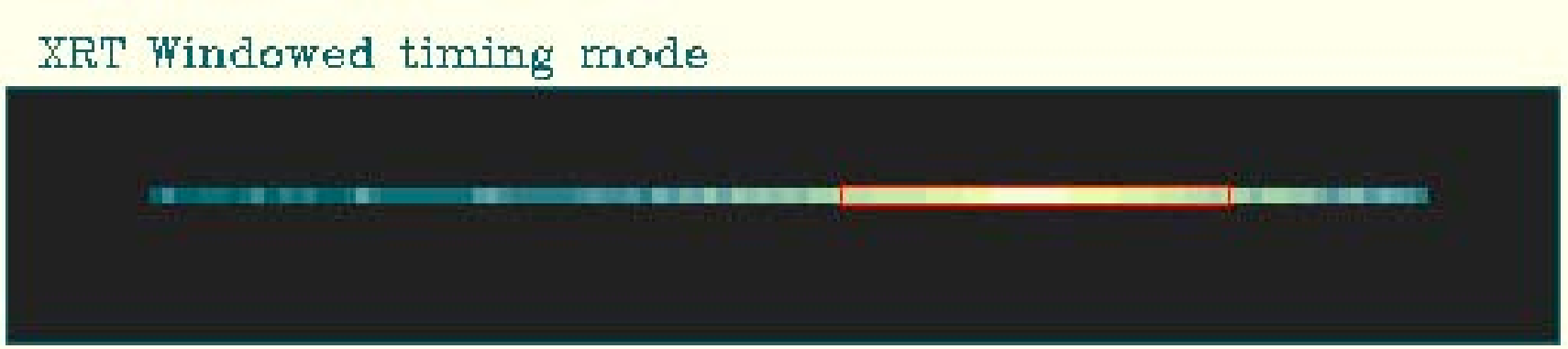
- Schedule xselect and xrtmkarf to extract average products for a given mode and corresponding arf

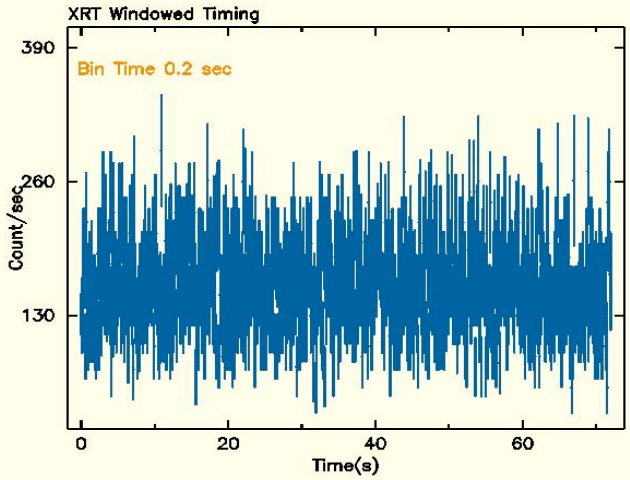
Photodiode picture

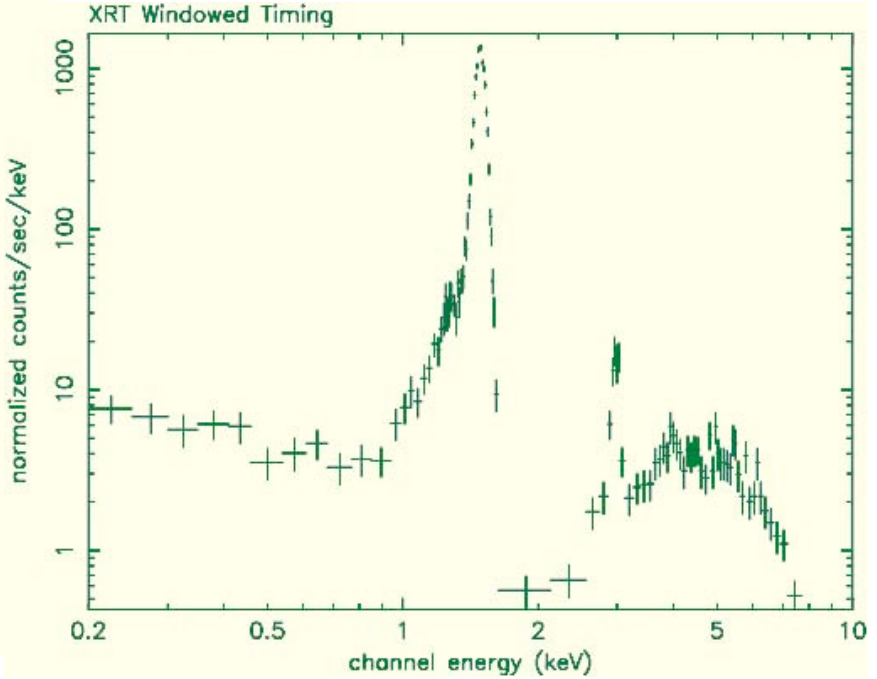




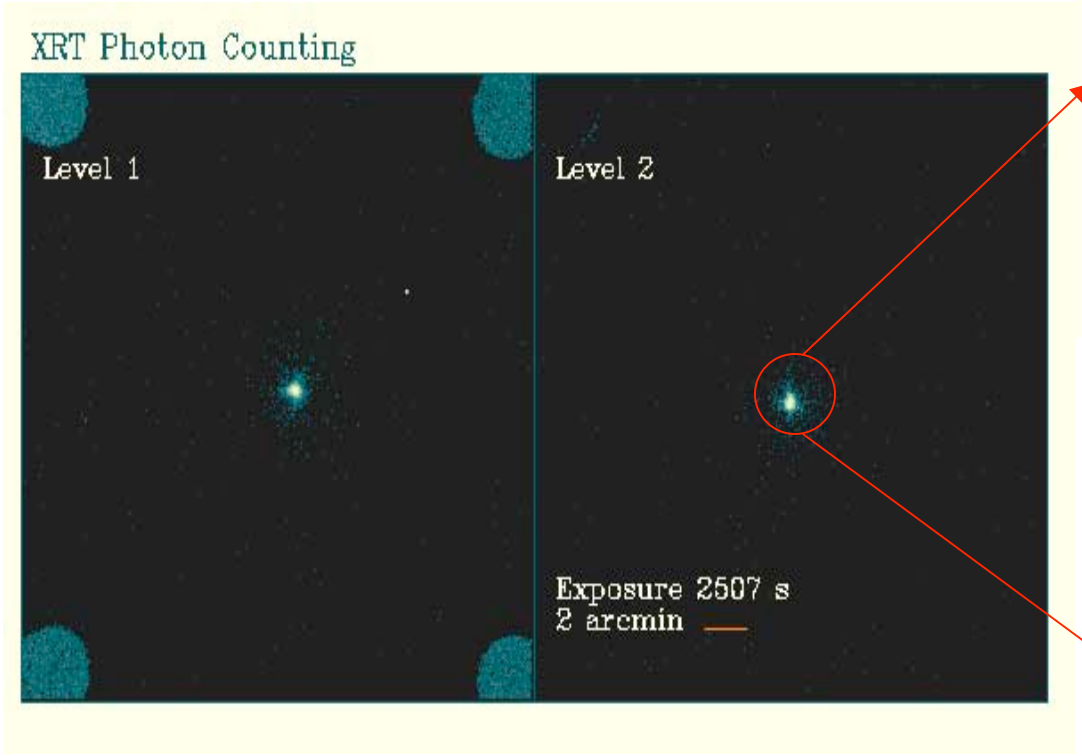
Windowed picture

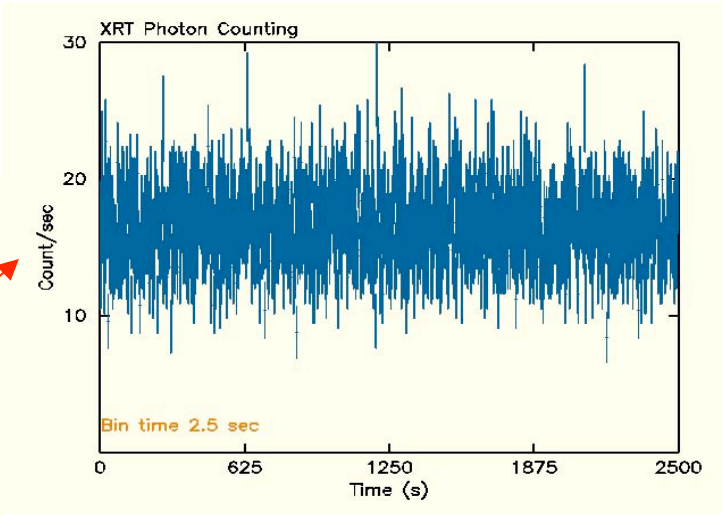


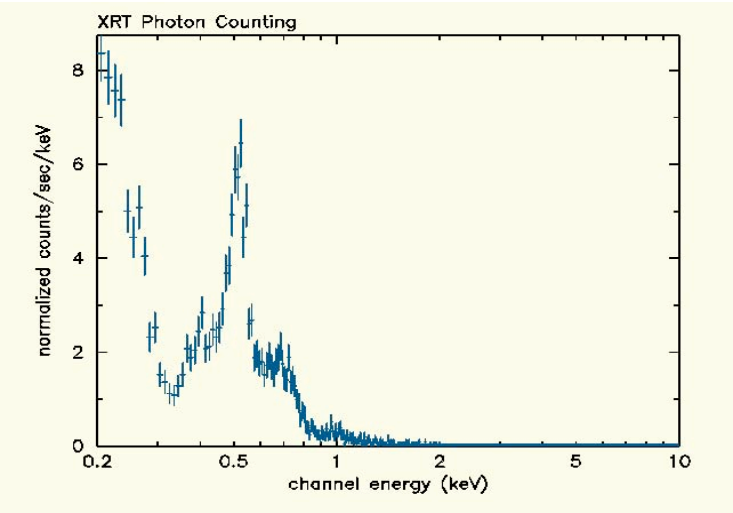




Photon counting picture







xrtpipeline : How everything is tight together

$ xrtpipeline indir=/archive/swift/00073130001 steminputs=sw00073130001 outdir=./ srcra=0 srcdec=0

Timing Modes (PD & WT):

- xrthkproc
- xrtfilter
- xrtflagpix (WT only)
- xrtpdcorr (PD only)
- xrttimetag
- xrtevtrec
- xrtcalcpi

Stage 1

- xrtscreen — Stage 2
- xrtproducts — Stage 3

Photon Counting Mode:

- xrtfilter
- coordinator
- xrtflagpix
- xrtpcgrade
- xrtcalcpi

Stage 1

- xrtscreen — Stage 2
- xrtproducts — Stage 3

Imaging mode:

- xrtscreen
- xrtimage
- swiftxform

Stage 1

TDRSS Processing

The XRT messages sent via TDRSS are :

If the XRT is able to calculate on board the centroid position

- **Centroid**
- **Image 51x51 pixels raw coordinates**

If the XRT is unable to obtain on board the centroid

- **Error centroid message**

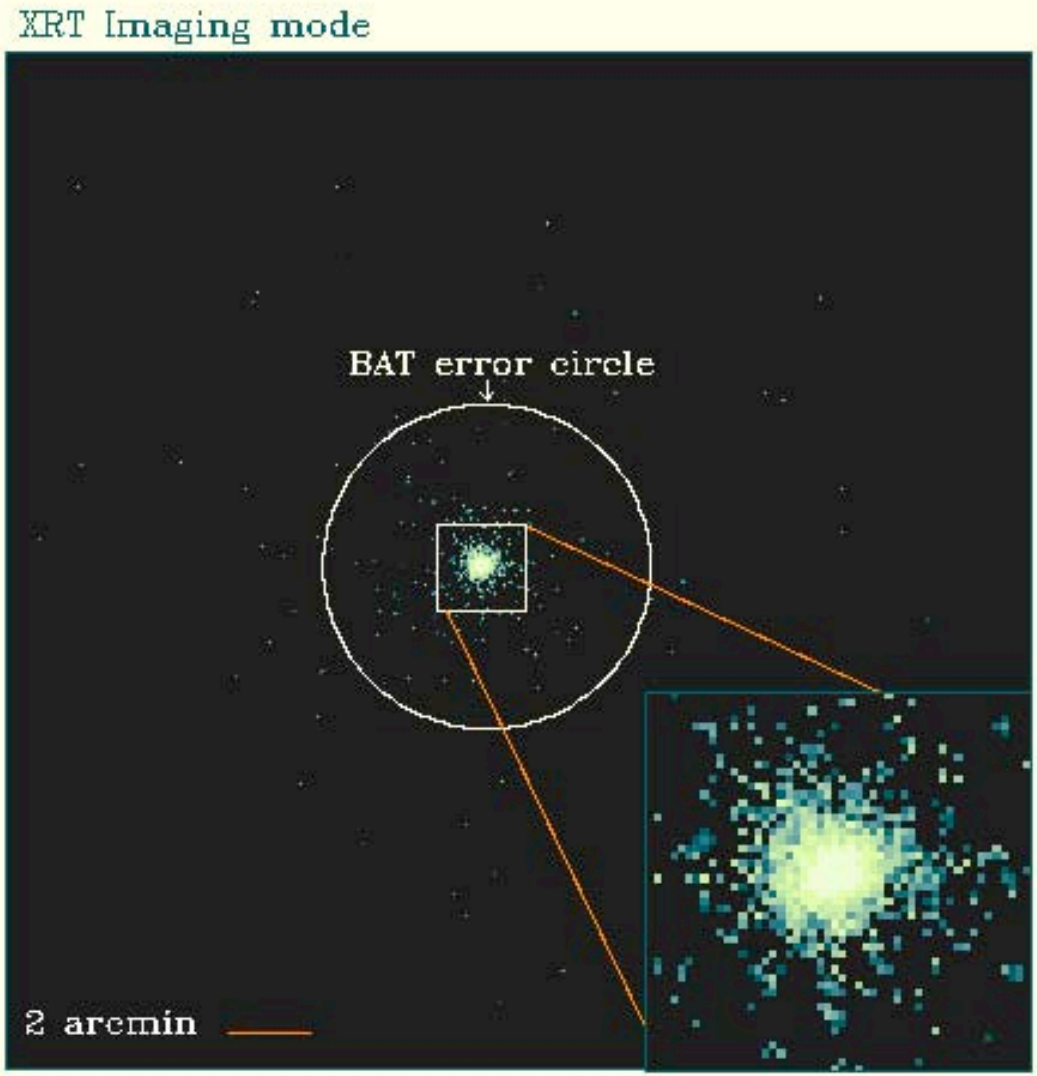
In addition

- Two spectra
  - a) LR & WT or
  - b) LR & WT +LR
- Light curve (100 bins)

Before broadcasting via GCN all messages are formatted in FITS.
Additional processing is necessary before the GCN for the:

- **Image message**:
  Bias subtraction, error centroid, flux estimate (based on a Crab spectrum), reference sky coordinates
- **Spectra message :**
  Depending which pair come down, subtract the bias from LR (a & b) and subtract the LR from the WT (b)

Imaging picture



Backup slides

TAM correction

xrttam:

- Corrects attitude file using TAM image centroid positions and reference LED positions.
  - Script using ’det2att' and ’attcombine' (multi-mission tasks)
    - From the shift of the LED positions recorded, computes corrections to XRT detector coordinates (Δ DETX, Δ DETY). XRT-PSU-037
    - det2att : (Δ DETX, Δ DETY) are translated into attitude corrections
    - attcombine: Corrections are applied to the attitude file
- Info from: CALDB TAM file and teldef file

NOTE: Corrected attitude used in the ‘coordinator’

Input asked: HK file, attitude file

Output: corrected attitude file, TAM correction in detector coordinates